Original Article

Impact of Acid and Fluoride containing mouthwash

Impact of Acid and Fluoride Containing Mouthwash on Corrosion of Stainless Steel Orthodontic Wires: In-Vitro Study

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ABSTRACT

Objective: This project aimed at selecting the least corrosive mouthwash that can be prescribed by working practitioners during the orthodontic treatment when their patient is being treated with Stainless Steel (SS) wire for longer periods.

Study Design: Comparative study.

Place and Duration of Study: This study was conducted at the Institute of Space Technology (IST) Islamabad. Standard medium for this study i.e., artificial saliva was prepared at the Interdisciplinary Research Centre in Biomedical Materials (IRCBM) Comsats University, Lahore from December 2018 to April 2019.

Materials and Methods: A comparative study was designed between acid and fluoride-containing mouthwashes for a valuable addition in the existing literature by evaluating corrosive effects on orthodontic wires. Sample wires were properly cleaned and coated with an epoxy resin. Two types of mouthwashes were used as test solutions whereas artificial saliva was considered as a standard test solution. After testing the wires, their surface morphology was explored under a Field Emission Scanning Electron Microscope (FESEM). The numeric data were then statistically analyzed by One-Way ANOVA using the SPSS version 23.0.

Results: Mouthwash containing HCl in 0.15% w/v of Benzydamine Hydrochloride showed lesser corrosion than the one having Fluoride content in 0.05% w/v of Sodium Monofluorophosphate.

Conclusion: This study suggested that in clinical practice, acid-containing mouthwash should be preferred over fluoride-containing mouthwashes when SS wires are employed for longer durations during the orthodontic treatment.

Key Words: Corrosion, Mouthwashes, Archwires, Stainless steel.

Citation of article: Wajahat M, Moeen F, Hassan M, Mustafa F, Hashmi ML, Siddique S. Impact of Acid and Fluoride containing mouthwash on Corrosion of Stainless Steel Orthodontic wires: In-Vitro Study. Med Forum 2020;31(8):63-67.

INTRODUCTION

Orthodontic treatment involves the alignment of malaligned and crowded teeth, intending to improve the function and aesthetics of the dentition. Malocclusion is a risk factor for plaque retention which is prone to gingival as well as caries. The corrosion due to chemical reactivity may lead to roughened surface and weakening of wire, leading to mechanical failure of the orthodontic device[1-3].

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Received: April, 2020
Accepted: May, 2020
Printed: August, 2020

As in prolonged orthodontic treatments, fluoride and acid concentrations in the oral cavity can have negative effects on Stainless Steel (SS) wires[4]. Owing to its ionic properties, the environment of the oral cavity is encouraging to metal wire degradation causing the release of metal ions[5]. Metal ions can be released regardless of protective oxide film present on metal wires.[1] Two simultaneous chemical reactions that occur on the metal surface are:

i. Oxidation (anodic reaction): Results in the production of ferrous ions (Eq. 1).

$$Fe_{(aq)} \rightarrow Fe^{2+}_{(aq)} + 2e^-_{(aq)} \quad \text{Eq. 1}$$

ii. Reduction (cathodic reaction): Results in the production of hydroxide ions (Eq. 2), water (Eq. 3), or hydrogen gas (Eq. 4), when electrons produced by the anodic reaction are consumed.

$$O_2 + 2H_2O_l + 4e^-_{(aq)} \rightarrow 4OH^- \quad \text{Eq. 2}$$

$$O_{2(aq)} + 4H^+_{(aq)} + 4e^-_{(aq)} \rightarrow 2H_2O_{(l)} \quad \text{Eq. 3}$$

$$2H^+_{(aq)} + 2e^-_{(aq)} \rightarrow H_{2(g)} \quad \text{Eq. 4}$$

Eq. 3 and 4 are most relevant to the corrosion of wires in an oral environment.

The solution type defines the extent of corrosion. Metals in the oral cavity are challenged by different acidic contents, due to which the cathodic and anodic reactions are enhanced leading to the dissolution (corrosion) of metal. Therefore, higher levels of acid or fluoride inside the oral cavity due to the use of acid or fluoride mouthwashes respectively can increase the process of corrosion[6].

Solutions containing fluoride and chloride could cause corrosion to orthodontic NiTi wires[7]. So, it could infer that mouthwashes containing these contents can corrode SS orthodontic archwires as well[8-10]. The present study was designed to compare the effects of acid-containing and fluoride-containing mouthwashes on SS archwires so that the practicing dentists could choose the least corrosive mouthwash for orthodontic patients before prescribing it.

MATERIALS AND METHODS

This study utilized 0.012 SS wires (N=30; Ortho Organizer™, USA) and two types of mouthwashes. 0.012 wires were preferred based on their long term use in the oral cavity during treatment.[11] Artificial saliva was employed as a standard medium.[12.]

Wires were cut, 2cm length was exposed for electrochemical corrosion testing and the rest of the area was coated with '5052 Epolam' epoxy resin because of its high insulation and ethanol immiscible property. Coated wires were dried overnight and then cleaned using ethanol in ultrasonic probe sonicator followed by distilled water wash.

Each wire before testing was immersed in the respective test solution for about 2-3 hours to achieve a stable open circuit potential. This is important as misleading values of already existing potential are avoided when the external potential is applied.[13]

Potentiodynamic testing employs a euro cell containing the test solution. This euro cell connects with a potentiostat (Gamry, R-600). Uncoated part of the sample wire was immersed into 100 ml of the test solution. In the euro cell, a saturated calomel electrode was used as the reference electrode and graphite rod as the counter electrode. A potential starting from -500 mV to 1500 mV with a scan rate of 1 mV/s was applied. The potentiodynamic polarization curves obtained were analyzed using Echem analyst software to calculate the corrosion rate of wires in different test solutions.

The surfaces of SS wires after the corrosion testing were observed using FESEM (MIRA3 TESCAN). One-way ANOVA using SPSS-23 was conducted to compare the mean corrosion rates of SS wires.

RESULTS

Polarization curves were obtained as a result of potentiodynamic corrosion testing. For the assessment of corrosion susceptibility of metal wires, these polarization curves were used as they provided information on passivity, corrosion rate and pitting susceptibility. The potentiodynamic polarization curves of SS wires in three test solutions are given in Fig. 1.

Fig. 1 represents a series of potentiodynamic polarization curves, the cathodic section (passive region i.e, from 0.5V to 0.4 V, for standard solution) of these polarization curves have shown no vertical stage and consisted only of one smooth slope. Afterward, the cathodic stage anodic stage (active region i.e, from 0.4V to 1.3 V) starts. The corrosion potentials of sample wires in three test solutions were close to each other with small peaks in the anodic current. So, the polarization behavior of acid-containing mouthwash showed nobler performance than that of fluoride-containing mouthwash because they exhibited lower values of current density i.e, better corrosion resistance.

SEM analysis showed less corrosion in acid and more in fluoride mouthwash. This surface characterization of tested wires support the results that were obtained from corrosion rates (Table 2). Fig. 3 clearly shows increased surface roughness as compared to Fig. 2

Statistical analysis showed that there was a significant difference in the corrosion rates of SS wires immersed in three solutions ($p<0.001$).

Table No.1: Chemical composition

Sr.No.	Test solution	Composition
1.	Enziclore [a]	Chlorhexidine gluconate (0.2% w/v) Benzydamine hydrochloride (0.15% w/v)
2.	Secure [a]	Sodium monofluorophosphate (0.05% w/v)
3.	Artificial saliva [b]	NaCl, KCl, KSCN, KH_2PO_4, $CO(NH_2)_2$, $CaCl_2.2H_2O$, $Na_2SO_4.10H_2O$, NH_4Cl, $NaHCO_3$

[a] Platinum Pharmaceuticals [b] Courtesy: IRCBM

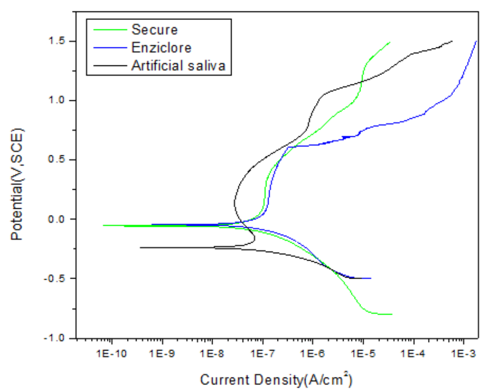

Figure No.1: Polarization curves

Table No.2: Corrosion parameters

Sample	Solutions	E_{corr}(mV)	I_{corr}(nA/cm^2)	Corrosion rate(MPY)
SS	Artificial saliva	-123 -120 -140 ND ND -159	3.950 7.200 4.810 ND ND 27.60	1.836x10^{-3} (0.001836) 3.350x10^{-3} (0.00335) 2.237x10^{-3} (0.002237) 2.792x10^{-3} (0.002792) 6.8x10^{-3} (0.0068) 12.83x10^{-3} (0.01283)
	Acid mouthwash (Enziclor^{TM})	-118 -131 -114 -62.40 407 44.10	63 115 132 36.80 22.10 74.10	29.30x10^{-3}(0.0293) 53.5x10^{-3} (0.0535) 61.28x10^{-3} (0.06128) 34.25x10^{-3} (0.03425) 20.57x10^{-3} (0.02057) 34.47x10^{-3} (0.03447)
	Fluoride mouthwash (Secure^{TM})	-97.6 -93.3 51.20 -44.80 -154 -152	651 643 337 312 334 328	302x10^{-3} (0.302) 299x10^{-3} (0.299) 313x10^{-3} (0.313) 290x10^{-3} (0.29) 310.8x10^{-3}(0.3108) 304.7x10^{-3}(0.3047)

* E_{corr}=Corrosion potential, I_{corr}=Current density, MPY=Mills Per Year

Table No. 3: Post Hoc Tukey Analysis.

Multiple Comparisons						
Dependent Variable: Corrosion Rate (MPY)						
(I) Immersion Media	(J) Immersion Media	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
Artificial Saliva	Enziclore	-.034*	.006	.000	-.049	-.018
	Secure	-.298*	.006	.000	-.314	-.283
Enziclore	Artificial Saliva	.034*	.006	.000	.018	.049
	Secure	-.264*	.006	.000	-.279	-.249
Secure	Artificial Saliva	.298*	.006	.000	.283	.314
	Enziclore	.264*	.006	.000	.249	.279

*The mean difference is significant at the 0.05 level.

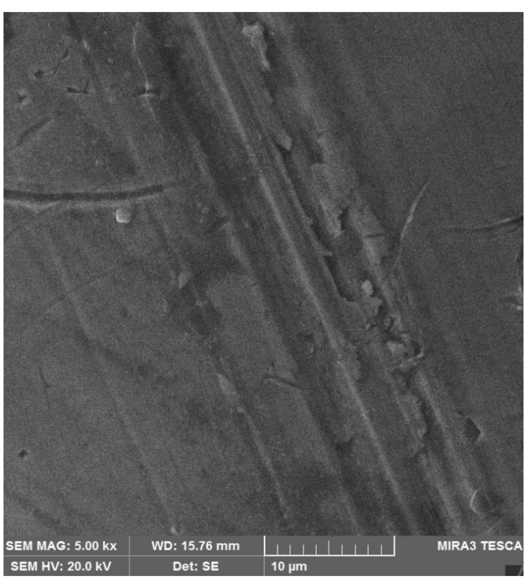

Figure No.2: SEM analysis of SS wire after potentiodynamic test in acid mouthwash

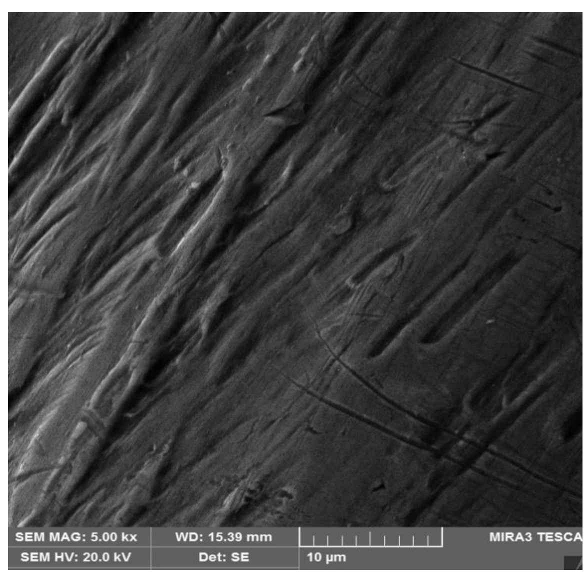

Figure No.3: SEM analysis of SS wire after potentiodynamic test in fluoride mouthwash

The comparison obtained by using Post Hoc test revealed that there was a significant difference between the corrosion of the SS wire in artificial saliva, acid-containing mouthwash and fluoride-containing mouthwash with a negative value which indicated that corrosion was less in artificial saliva as compared to both types of mouthwashes. Furthermore, acid-containing mouthwashes were found to be less corrosive in nature as compared to fluoride-containing mouthwashes with a significance level of 0.001, as mentioned in Table 3.

DISCUSSION

Results showed that the value of current density was found to be lowest in artificial saliva i.e. 3.950 nA/cm^2 among the values of all the immersion media. Between acid and fluoride-containing mouthwashes, the lowest current density was found in acid-containing mouthwash i.e. 22.10 nA/cm^2. The lowest value of current density represents the lowest corrosion rate[14]. Highest value of current density was found in fluoride containing mouthwash i.e. 651 nA/cm^2 depicting fluoride medium as the most corrosive of all the three media used. The curve having more fluctuations in the anodic section has more pitting effect e.g. the curve of fluoride mouthwash test has more fluctuations as compared to the curve of the test in acid mouthwash which has lower fluctuations. Test in artificial saliva showed lowest fluctuations of potentiodynamic curve thus giving lower values of corrosion current i.e, representing the lowest corrosion rate[15].

The mean corrosion rate of fluoride-containing mouthwash was found to be greatest i.e., 0.30325 MPY whereas the corrosion rate of SS wires in acid-containing mouthwash was calculated as 0.038895 MPY. This difference in corrosion rate states the safety of acid-containing mouthwashes against fluoride ones while the patient is being treated with SS wire for longer periods of time.

Due to the complex morphologies of orthodontic appliances, plaque retention increases during orthodontic treatment. Therefore, it is of utmost importance to maintain oral hygiene during the long period of the treatment. Although Fluoride mouthwashes are found to be more corrosive but rinsing with fluoride mouthwashes on daily basis is essential for caries prevention because of the ability of fluoride ions in promoting the formation of calcium fluoride globules which are helpful in stimulating remineralization[15-17]. Hence to avoid corrosion and take benefits of fluoride mouthwash as well, time is an important factor to be considered. The corrosion rate obtained here is in Mills per Year i.e., corrosion in one year. For short term treatment with SS wire, fluoride mouthwashes can be used.

Ide et al. reported that bacteria in the plaque which is hoarded on the appliance surfaces during the course of orthodontic treatment leads to the corrosion of metal surfaces[18]. Literature established that adding to this oral environment, corrosion is enhanced through the release of ions from the surface of the metal as a result of mouthwash use[11,19-22].

The SS wires in sodium monofluorophosphate group had significantly greater corrosion than the other mouthwash ($p < 0.001$). The composition of a passive layer of SS wires is Cr_2O_3/Fe_2O_3.[23,24] Corrosion starts when this corrosion resistant barrier is compromised. Chemical constituents of mouthwashes play an important role in the disruption of the corrosion resistant barrier. However, Enziclor™ contains chloride ions, while Secure™ contains fluoride ions. SS wires exposed to fluoride ions display a much higher corrosion rate, in comparison to the wires exposed to chloride ions. According to Erdogan et al., ions were released by various mouthwashes, the study determined that the highest amount of ion release was found in mouthwashes comprising of sodium fluoride and alcohol[20]. Higher level of ions released leads to higher corrosion.

In a study by Nalbantgila, it was shown that chlorhexidine gluconate and benzydamine hydrochloride containing mouthwashes exhibited the least corrosion[25]. This is in accordance with the results of the present study, where acid-containing mouthwash showed the least corrosion as compared to the other mouthwash. Higher corrosion rate can lead to the loss of physical properties of SS wires. The primary role in the smooth execution of orthodontic treatment is played by the physical properties of the wires. Therefore, to maintain the properties of SS wires for longer periods of time, mouthwashes which show increased corrosion resistance should be preferred as least corrosive mouthwashes are more likely to prevent the corrosion defects on the wire surface. This will increase friction which slows down the process treatment and is detrimental to the success of treatment.

The SEM images show lengthy wedges in a specific direction. Due to cold rolling, the grains are aligned along the direction of rolling. These aligned sections become more vulnerable to corrosion and lengthy wedges are formed.

CONCLUSION

Acid-containing mouthwashes have better corrosion resistance than fluoride-containing mouthwashes because the former one showed lesser fluctuations on the potentiodynamic scan and lesser corrosion rate on SS wires (MPY). The I_{corr} value of acid-based mouthwashes is 20% less. Hence the dentist should prefer prescribing acid-containing mouthwashes while the patient is being treated with SS wire for a longer time period i.e, more than one year. Otherwise, for short durations of treatment with SS wires, fluoride mouthwashes can be recommended.

Author's Contribution:

Concept & Design of Study:	Mehreen Wajahat
Drafting:	Faisal Moeen, Muhammad Hassan
Data Analysis:	Faisal Mustafa, Muhammad Luqman

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Revisiting Critically:	Mehreen Wajahat, Faisal Moeen
Final Approval of version:	Mehreen Wajahat

Conflict of Interest: The study has no conflict of interest to declare by any author.

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